A Novel Interhemispheric Dural Inversion Technique for Indirect Parafalcine Cerebral Revascularization: Case Report

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BACKGROUND AND IMPORTANCE: Variety of revascularization strategies have been deployed to treat the deterioration of cerebral blood flow. Blood flow restoration can be achieved by direct or indirect procedures. The indirect reconstructive procedure to augment blood flow involves encephalomyosynangiosis, encephaloduroarteriosynangiosis, or encephalodurosynangiosis, and has been used effectively in ischemic Moyamoya disease. However, the preferred procedure must be evaluated on a case-by-case basis and remains controversial in other cerebral arterial diseases. Here, we report the "interhemispheric dural inversion (IDI)" as a novel technique for indirect parafalcine cortical revascularization.

CLINICAL PRESENTATION: A 54-year-old white man with a complex history of neck radiation secondary to childhood Hodgkin's lymphoma presented with focal perfusion deficit in the right mesial occipital lobe near the primary visual cortex. A large c-shaped dural flap with a paramedian base is harvested and, after an interhemispheric dissection, placed in contact with the ischemic parafalcine cortical tissue (IDI).

CONCLUSION: The IDI was used successfully for indirect revascularization of a focal right paramedian occipital lobe deficit in a 54-year-old man with complex cerebro-occlusive disease from childhood radiation and multiple previous bypass surgeries. The IDI is a simple approach for targeted indirect parafalcine cortical revascularization to facilitate an increased blood supply and prompt new vessels to sprout from preexisting dural arteries. It can be used as a standalone technique or combined with other revascularization strategies, as warranted.

KEY WORDS: Ischemia, Encephalodurosynangiosis, Bypass, Moyamoya, Stroke, Revascularization, Angiogenesis

The World Health Organization has ranked cerebrovascular diseases, including cerebral arterial steno-occlusive diseases, as the second leading cause of death, after ischemic heart disease.[1,2] This concerning statistic demands increasing efforts from the neurosurgical field to innovate new therapeutic approaches to reduce morbidity and mortality. Current treatments for cerebral arterial steno-occlusive diseases include direct, indirect, or combined revascularization procedures.[3-6] These procedures can involve intracranial-to-intracranial or extracranial-to-intracranial bypass.[7,8]

ABBREVIATIONS: IDI, interhemispheric dural inversion; **PCA,** posterior cerebral artery; **SSS,** superior sagittal sinus; **STA,** superficial temporal artery; **VA,** vertebral artery.

Common extracranial-to-intracranial revascularization procedures include direct bypass, which most commonly involves anastomosis of the superficial temporal artery (STA) to the middle cerebral artery (MCA; STA-MCA), which is a low flow direct construct. Indirect techniques include laying muscle (encephalomyosynangiosis), a scalp artery with a galeal-adventitial cuff (encephaloduroarteriosynangiosis), dura alone (encephalodurosynangiosis), or any combination of the above on the cerebrum for indirect secondary vascular growth.[9] Variations of these strategies include combined bypass and/or higher-flow direct bypasses using interposition grafts.[9-11] Encephaloduroarteriosynangiosis was first introduced by Matsushima in 1980 for the surgical management of pediatric Moyamoya patients.[12-19] Today, this approach is used not only in the treatment of Moyamoya disease, but also in cerebral arterial steno-occlusive diseases.[20-22]

Building on this literature, we report a novel variation of encephalodurosynangiosis, termed an "interhemispheric dural inversion (IDI)," for revascularization of a focal paramedian occipital lobe perfusion deficit.

CASE PRESENTATION

Institutional review board approval was not sought for this study as no protected health information or identifiable information was used. The patient consented to the procedure and to the publication of his image.

Clinical Presentation

A 54-year-old man with a complex history of neck radiation secondary to childhood Hodgkin's lymphoma presented for a neurosurgical consultation. At age 9 years, he had a tumor resected and received radiation therapy. He has since been in remission but developed bilateral common carotid artery occlusions and a proximal right vertebral artery (VA) occlusion from the radiation. At age 37 years, he suffered a cerebrovascular accident secondary to global hypoperfusion, for which he was treated with bilateral revascularization: a right subclavian to right V3 bypass using a saphenous vein graft and, several months later, a left subclavian to left internal carotid artery using a saphenous vein graft. He was maintained on daily aspirin. More than a decade later, the patient presented after episodes of blurry vision, with MRI (3T Siemens Magnetom Prisma MRI System) demonstrating new right punctate occipital lobe infarct (Figure 1A). A catheter angiogram showed complete occlusion of bilateral common carotid arteries, a nonpatent left carotid bypass, a patent native left VA, a patent right subclavian to V3 bypass, and severe stenosis of the right distal posterior cerebral artery (PCA) (Figure 1B). Computerized tomography (Siemens Medical Solutions USA, Inc.) perfusion imaging demonstrated a focal perfusion deficit in the right mesial occipital lobe near the primary visual cortex. On neurologic examination, he had a left lower quadrantanopia and moderate expressive aphasia but was otherwise neurologically intact. Given his focal paramedian deficit that is challenging for direct revascularization, as well as his previous occluded bypass, an indirect treatment with a dural inversion into the interhemispheric fissure to revascularize the primary visual cortex was recommended.

Operative Technique

The patient was intubated with mean arterial pressures above his baseline and placed in a park bench position with the right side down. His head was secured in a Mayfield attachment. The parieto-occipital superior sagittal sinus was mapped using neuronavigation (Medtronic StealthStation^{TM}), and a horseshoe incision was marked that would allow for a dural flap large enough to reach the falcotentorial junction (Figure 2A). Intravenous antibiotics and antiepileptics were administered as standard preoperative care, with no diuretics used to preserve cerebral perfusion. The incision was prepared and opened using a #10 blade, and the flap was elevated in a subperiosteal fashion and reflected with hooks. An occipital craniotomy was performed, and an extracoarse diamond drill was used to extend the craniotomy to the edge of the superior sagittal sinus medially. Under the operating microscope (Kinevo900, Carl Zeiss Meditec), the dura was opened with a #15 blade and a c-shaped durotomy with a medial base was opened with scissors. An interhemispheric dissection was performed to the falcotentorial junction, with neuronavigation used to verify the location of interest (Figure 2B). The dural flap was inverted and laid within the interhemispheric space down to the falcotentorial junction, ensuring it was opposed to the mesial right occipital lobe. A

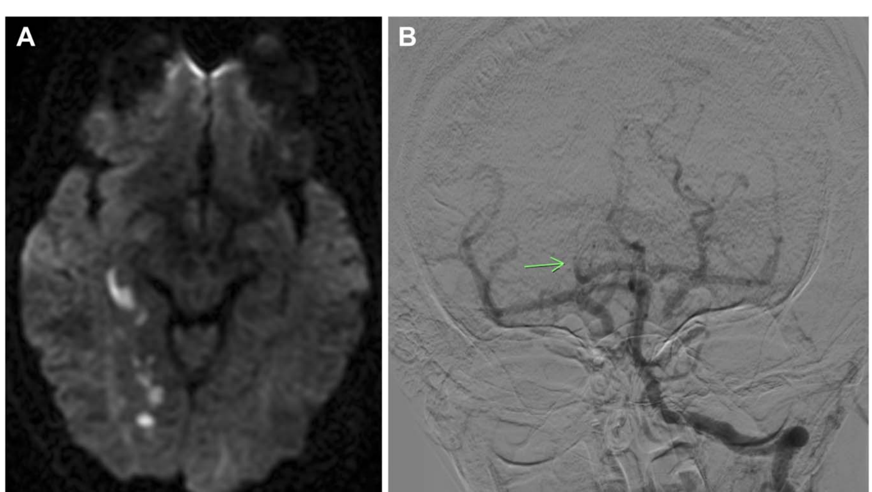

FIGURE 1. **A**, *Preoperative MRI demonstrating a focal new right punctate occipital lobe infarct.* **B**, *Preoperative diagnostic cerebral angiogram demonstrating severe right posterior cerebral artery narrowing (green arrow).*

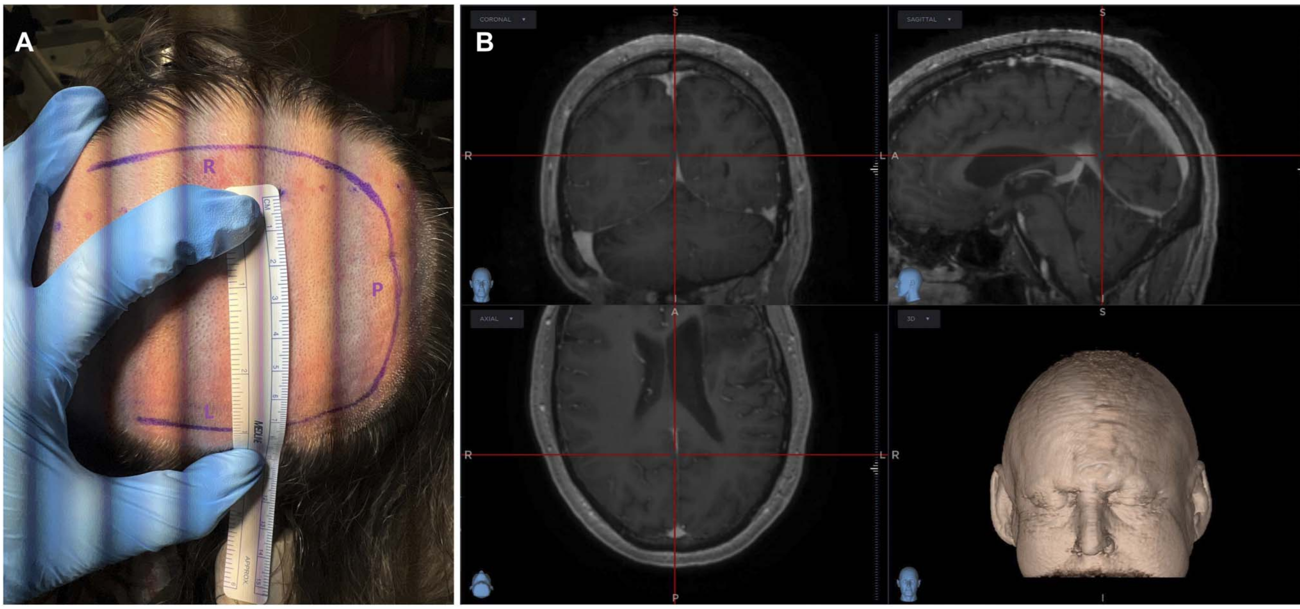

FIGURE 2. *Intraoperative neuronavigation to mark and verify incision site.* **A**, *An illustration of a horseshoe incision to access falcotentorial junction before incision (P; posterior, R; right side, L; left side).* **B**, *A neuronavigation image to verify the falcotentorial junction after craniotomy.*

synthetic dural graft was placed over the exposed occipital lobe, and the bone was replated. The skin was closed in a standard layered fashion (Figure 3 and Video). Estimated blood loss was 100 ccs, and surgical time was <2 hours. Postoperatively, the patient was at his neurological baseline and was discharged home on postoperative day 2.

Follow-up

The patient remained at his neurological baseline at 3 weeks, 6 weeks, and 12 months. Postoperative catheter angiogram at 6 months showed stable multiple arterial occlusions; however, the computerized tomography perfusion imaging at 12 months demonstrated improved perfusion of the right primary visual cortex (Figure 4).

DISCUSSION

The incidence of cerebrovascular diseases is expanding because of the aging population and advances in technology.[23] Therefore, multiple techniques for cerebral revascularization have been developed to address the variety of clinical scenarios that can result

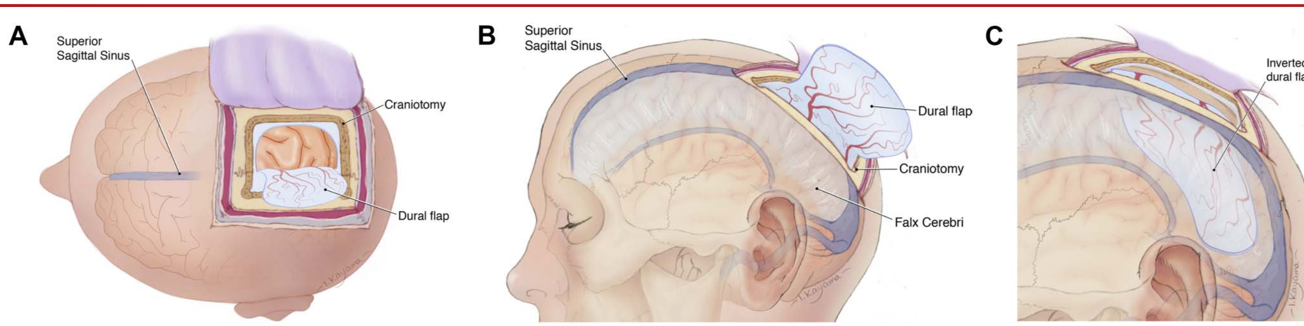

FIGURE 3. *Schematic illustration of the IDI technique in a 54-year-old white man with a complex arterial steno-occlusive disease.* **A**, *Anatomic diagram of the skin incision and craniotomy for an interhemispheric exposure and approach to the falcotentorial junction. Superior view demonstrating the SSS location in relation to surgical horseshoe incision and dissected interhemispheric dural flap.* **B**, *Inversion of dissected interhemispheric dural flap, in right lateral side of SSS, leads the surgeon to the interhemispheric space down to the falcotentorial junction.* **C**, *Sagittal view of dural flap in the interhemispheric space down to the falcotentorial junction in relationship to SSS, falx cerebri, transverse sinus, straight sinus, and inferior sagittal sinus. The IDI is opposed to the mesial right occipital lobe (right primary visual cortex). IDI, interhemispheric dural inversion; SSS, superior sagittal sinus.*

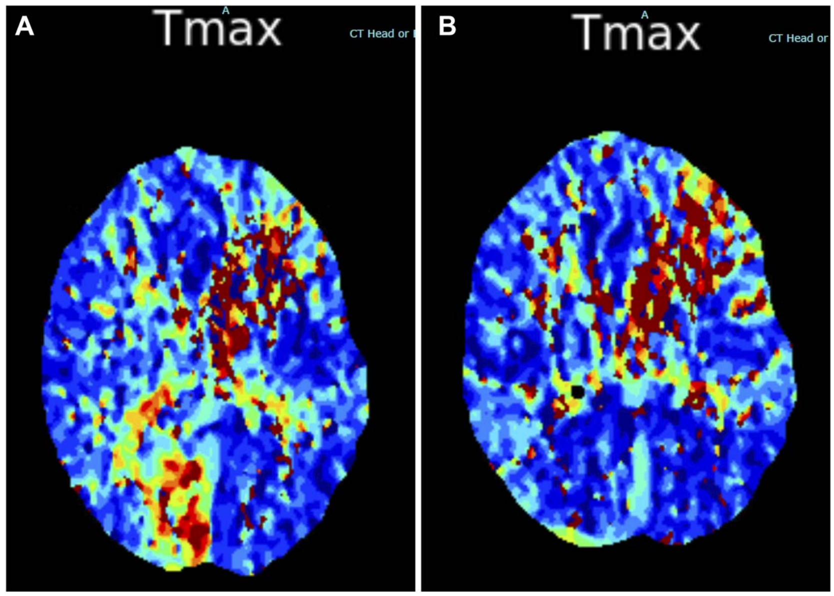

FIGURE 4. *Computer tomography perfusion imaging processed by using RAPID software program showing an improved time-to-maximum (Tmax) threshold* **A,** *before the interhemispheric dural inversion and* **B,** *12 months after the surgery. The focal hypoperfusion in the right mesial occipital lobe near the primary visual cortex has improved after surgery, suggestive of improved perfusion after the indirect revascularization.*

from cerebral arterial steno-occlusive disease. Although the most common strategies for cerebral revascularization are direct and indirect techniques, these approaches can have limited utility in some cases.[24] We and others have described alternative approaches, such as a comprehensive anatomic evaluation for developing a revascularization construct.[5,25]

The key results in the presented case are the paramedian focal area of occipital lobe ischemia precluded use of standard STA grafts because of inadequate length of the artery to reach the target area in the brain. A conventional occipital artery graft was also deemed suboptimal because of the patient's generalized occluded common carotid artery, prolonged surgical time, prolonged anesthesia time, and arterial graft length limitations. Other external carotid artery to PCA or VA to PCA bypasses with interposition grafts were not selected because of both inadequate donor arteries such as the diameter of the donor artery vs recipient artery, and significant size mismatch from any interposition graft into a recipient vessel. Such constructs would also result in medium-to-higher flow direct revascularizations that would also potentially provide flow in excess of demand, risking hyperperfusion syndrome or hemorrhage.[26,27]

Limitations

In summary, this patient had an occluded common carotid artery, which precluded use of the carotid artery as a potential donor to reconstruct an occipital artery-interposition graft-P4 bypass. However, if the carotid donor was available, a smaller interposition graft, such as the descending lateral circumflex femoral artery, would be an optimal size match to the smaller P4 recipient. Given these limitations, the described IDI technique was the most straightforward option. The simplicity of this approach also facilitated a relatively short surgery, which was tolerated without complications.

To date, this technique has not been described in this context.[9-11,13-15,20,21,24,28] In general, this approach can also easily be adapted to indirectly revascularize (a) any supratentorial parafalcine cortex, or (b) can be combined with a pericranial graft harvest, (c) or application to the cortical convexity for simultaneous multiterritory indirect revascularization, and (d) and can be used in combination with any direct anterior cerebral artery or PCA revascularization strategies that use the interhemispheric corridor. While the occipital region is usually favorable for interhemispheric dissections due to fewer bridging veins, it is critical to carefully examine preoperative venous anatomy to identify the optimal approach, particularly in the frontal region where there are often more bridging veins present.[29]

Our overall interpretation is that although we successfully used the IDI technique for the first time here in a patient with symptomatic bilateral carotid stenosis, and his prospective follow-up demonstrated a better outcome, we do recommend the translation of the approach to a larger cohort of patients.

CONCLUSION

The IDI technique is a simple and customizable approach for targeted parafalcine cortical revascularization and can be used in combination with other revascularization strategies.

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Disclosures

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VIDEO. This video shows a novel interhemispheric dural inversion technique for indirect parafalcine cerebral revascularization. A dural flap was inverted and laid within the interhemispheric space down to the falcotentorial junction, ensuring it was opposed to the mesial right occipital lobe. For educational purposes here (01: 28 minutes), a live comprehensive recording of surgery was documented to demonstrate more details of surgical technique (Video 1; Vincent Nguyen MD). The participants and any identifiable individuals consented to publication of her/his image.

COMMENTS

In this article, the authors report their use of interhemispheric dural inversion (IDI) for indirect revascularization in a 54-year-old man with right mesial occipital lobe ischemia. This is an excellent presentation of encephalodurosynangiosis (EDS), a viable technique for indirect revascularization, particularly in deep areas where external carotid artery branch use for encephaloduroarteriosynangiosis (EDAS) may not be practicable.

While EDS and dural inversion have long been utilized,[1a-3a] the "interhemispheric version" of dural inversion was broached by Dauser et al[2a] in their article on EDAS with dural inversion. Here, they raised the possibility of constructing dural flaps based near the superior sagittal sinus, which can be tucked into the interhemispheric fissure for revascularization in the anterior cerebral artery territory.[2a] The authors have brilliantly applied this technique successfully in this patient. Their novel use of IDI is commendable, especially if it was conceived for use before they became aware of its earlier mention.

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